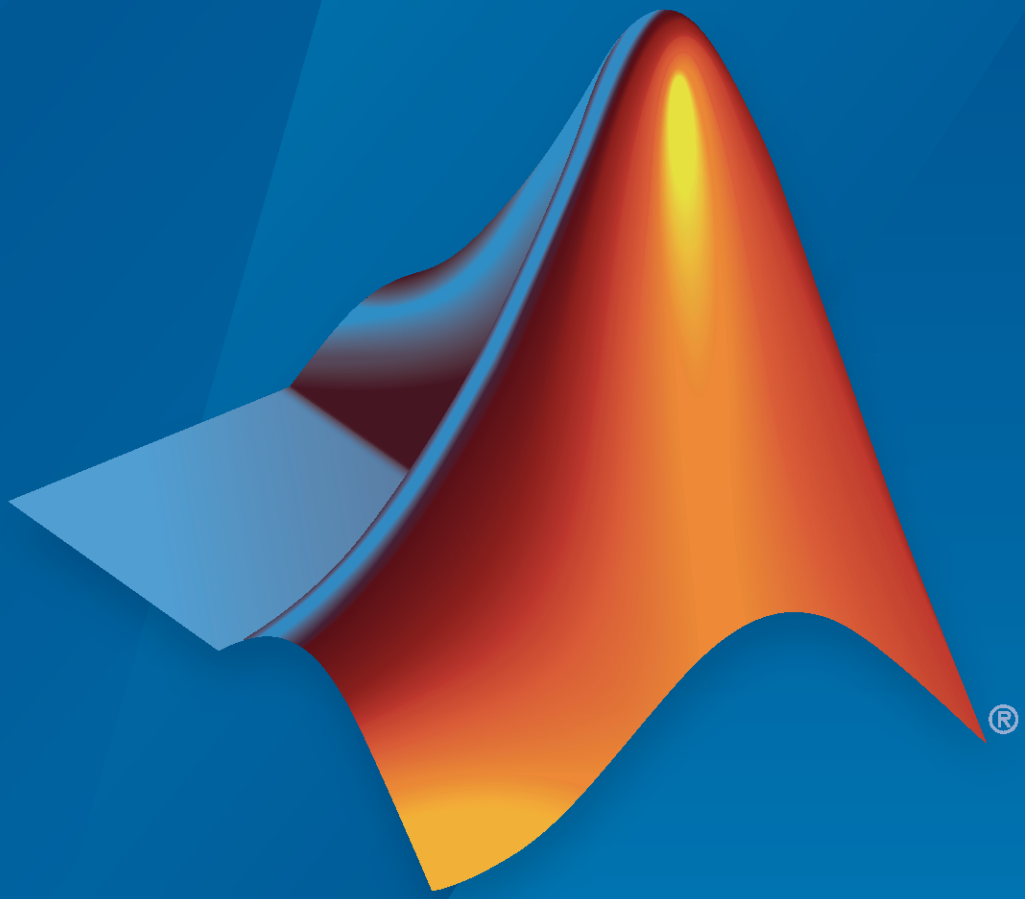
LTE Toolbox™ Release Notes



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LTE Toolbox™ Release Notes

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Version: 3.6

New Features

Bug Fixes

NB-IoT Downlink In-Band and Guardband Waveform Generation and Analysis

The “NB-IoT Downlink In-Band and Guardband Waveform Generation and Analysis” example shows how to generate a narrowband internet of things (NB-IoT) downlink waveform for in-band and guardband operation mode on an LTE carrier. The example also measures the error vector magnitude (EVM) of the recovered NB-IoT physical downlink shared channel (NPDSCH).

LTE Waveform Generator App Updates

The **LTE Waveform Generator** app now enables you to export LTE waveforms to Simulink®. Generate a waveform in a Simulink model by using the Waveform From Wireless Waveform Generator App block. For more information, see the “Generate Wireless Waveform in Simulink Using App-Generated Block” tutorial.

R2021a

Version: 3.5

New Features

Bug Fixes

NB-IoT Physical Random Access Channel

These functions support the narrowband physical random access channel (NPRACH) for the narrowband Internet of Things (NB-IoT), as specified in Release 15 of 3GPP TS 36.211.

Function	Description
`lteNBResourceGrid`	Narrowband resource grid
`lteNPRACH`	Generate NPRACH frequency division duplexing (FDD) waveform
`lteNPRACHInfo`	NPRACH resource information

MATLAB Online Support

MATLAB® Online™ now supports LTE Toolbox. For more information about supported toolboxes, see Specifications and Limitations.

R2020b

Version: 3.4

New Features

Bug Fixes

Configure and Generate Downlink RMCs with 256-QAM and 1024-QAM

Configure and generate R.68-1 (256-QAM) and R.105 (1024-QAM) downlink reference measurement channel (RMC) waveforms, as specified in Release 15 of 3GPP TS 36.101. You can generate and visualize these RMCs by using the **LTE Waveform Generator** app or using the `lteRMCDL` and `lteRMCDLTool` functions.

Look up the transport block sizes (TBSs) for 1024-QAM, as specified in Release 15 of 3GPP TS 36.213, by using the `lteTBS` function.

Generate Release 15 NPRACH FDD Waveforms

The NB-IoT PRACH Waveform Generation example shows how to generate frequency-division duplexing (FDD) waveforms containing the narrowband physical random access channel (NPRACH) for the narrowband Internet of Things (NB-IoT).

The example describes the FDD aspects of NPRACH allocation specified in Release 15 of 3GPP TS 36.211, configures and generates a compliant FDD NPRACH waveform, and visualizes the transmitted resource grid.

Model and Test LTE RF Transmitter

The Modeling and Testing an LTE RF Transmitter example characterizes the impact of radio frequency (RF) impairments, such as in-phase and quadrature imbalance, phase noise, and power amplifier nonlinearities, on LTE test model waveform transmission. The example demonstrates how to measure error vector magnitude (EVM), occupied bandwidth, channel power, and the complementary cumulative distribution function (CCDF) by using LTE Toolbox and RF Blockset™ software.

Visualize CDL Channel Characteristics

Visualize channel characteristics of clustered delay line (CDL) channel models by using the `displayChannel` object function of the `lte3DChannel` System object™. The function displays geometric and electromagnetic characteristics of the CDL channel model at the transmitter and receiver ends. The visualization includes the position, polarization, and directivity radiation pattern of the antenna elements, cluster path directions, and average path gains.

R2020a

Version: 3.3

New Features

Bug Fixes

NB-IoT Uplink Shared Channel Modeling

Generate and decode the narrowband Internet of Things (NB-IoT) uplink shared channel by using the `lteNULSCH` and `lteNULSCHDecode` functions.

Support for NPUSCH Channel Processing and DRS Generation

Generate and decode the narrowband physical uplink shared channel (NPUSCH) by using the `lteNPUSCH`, `lteNPUSCHDecode`, and `lteNPUSCHIndices` functions.

Generate the NPUSCH demodulation reference signals (DRSs) by using the `lteNPUSCHDRS` and `lteNPUSCHDRSIndices` functions.

NB-IoT Uplink Practical Synchronization and Channel Estimation

Measure the timing offset of NB-IoT uplink slots by using the `lteULFrameOffsetNPUSCH` function.

Estimate the channel for NB-IoT uplink slots by using the `lteULChannelEstimateNPUSCH` function.

R2019b

Version: 3.2

New Features

Compatibility Considerations

NB-IoT Physical Broadcast and Downlink Control Channels

These functions support the narrowband physical broadcast channel (NPBCH) and narrowband physical downlink control channel (NPDCCH) for the narrowband Internet of Things (NB-IoT) standard.

Function	Description
`lteNPBCH`	Generate encoded NPBCH symbols
`lteNPBCHIndices`	Get NPBCH resource element (RE) indices
`lteNPBCHDecode`	Decode modulated NPBCH symbols
`lteNPDCCH`	Generate encoded NPDCCH symbols
`lteNPDCCHIndices`	Get NPDCCH RE indices
`lteNPDCCHDecode`	Decode modulated NPDCCH symbols

NB-IoT Downlink Channel Estimation and Synchronization

Perform practical channel estimation for NB-IoT configurations by using the updated `lteDLChannelEstimate` function.

Measure the timing offset of NB-IoT downlink frames by using the `lteNBDLFrameOffset` function.

NB-IoT Downlink Signal Recovery Example

The NB-IoT Cell Search and MIB Recovery example shows how to synchronize, demodulate, and decode an NB-IoT downlink signal.

Wireless Waveform Generator App Updates

You can now export an LTE waveform generated using the **Wireless Waveform Generator** app as a MATLAB script with a `.m` extension. You can recreate the waveform by running the exported script in MATLAB.

Scan and Decode LTE Waveform Example

The Scan and Decode LTE Waveform example shows how to capture and decode LTE signals by using LTE Toolbox and relevant hardware support packages. The example launches a graphical user interface (GUI), which you can use to:

- Provide search settings required to search for LTE waveforms.
- Capture LTE waveforms generated by a range of hardware.
- Decode and analyze signal information.
- Visualize the received signal.

Release 15 1024-QAM Downlink Support

These downlink shared channel (DL-SCH) and physical downlink shared channel (PDSCH) functions now support 1024-point quadrature amplitude modulation (1024-QAM).

Function	Description
`lteCQISelect`	Calculate PDSCH channel quality indication
`lteDLSCH`	Apply DL-SCH encoding
`lteDLSCHDecode`	Apply DL-SCH decoding
`lteDLSCHInfo`	Get DL-SCH segmentation information
`lteLayerDemap`	Perform layer demapping of modulation symbols
`lteMCS`	Get modulation and coding scheme (MCS) information
`lteRateMatchTurbo`	Perform turbo rate matching
`lteRateRecoverTurbo`	Perform turbo rate recovery
`ltePDSCH`	Apply PDSCH encoding
`ltePDSCHDecode`	Apply PDSCH decoding
`ltePDSCHIndices`	Get PDSCH resource element (RE) indices
`lteSymbolModulate`	Generate modulated symbols
`lteSymbolDemodulate`	Demodulate symbols and convert to bits
`lteTestModel`	Generate downlink test model configuration
`lteTestModelTool`	Generate downlink test model waveform

Functionality Being Removed or Changed

Apps removed
Behavior change

In previous releases, the input-free syntaxes of the `lteRMCDLTool`, `lteRMCULTool`, and `lteTestModelTool` functions opened the **LTE Downlink RMC Generator**, **LTE Uplink RMC Generator**, and **LTE Test Model Generator** apps, respectively. These apps have been removed. Use the **Wireless Waveform Generator** app instead.

Starting in R2019b, input-free calls to these functions open the **Wireless Waveform Generator** app for the waveform type indicated in this table.

Function	Waveform Type
`lteRMCDLTool`	Downlink reference measurement channel (RMC)
`lteRMCULTool`	Uplink RMC
`lteTestModelTool`	E-UTRA test model (E-TM)

Syntaxes for lteRMCDLTool, lteRMCULTool, and lteTestModelTool functions will be removed
Errors

The syntaxes listed in this table will be removed in a future release. Update your code with the recommended replacement.

Function	Discouraged Syntax	Recommended Replacement Syntax
`lteRMCDLTool`	`[waveform,grid,rmccfgout] = lteRMCDLTool`	`lteRMCDLTool`
`lteRMCULTool`	`[waveform,grid,rmccfgout] = lteRMCULTool`	`lteRMCULTool`
`lteTestModelTool`	`[waveform,grid,tm] = lteTestModelTool`	`lteTestModelTool`

Note Discouraged syntaxes no longer assign output arguments. To assign output arguments, use an alternative function syntax or export a waveform generated using the **Wireless Waveform Generator** app.

R2019a

Version: 3.1

New Features

Wireless Waveform Generator App Updates

With the **Wireless Waveform Generator** app, you can now:

- Create waveforms compliant with specific LTE uplink and downlink reference measurement channel (RMC) and E-UTRA test model (E-TM) configurations.
- Generate a waveform that you can transmit with a connected lab test instrument. The Wireless Waveform Generator app can generate waveforms for instruments supported by the `rfsiggen` function. Use of the transmit feature in the Wireless Waveform Generator app requires Instrument Control Toolbox™.

NB-IoT Uplink Support: Perform perfect channel estimation and SC-FDMA demodulation

The `lteULPerfectChannelEstimate` and `lteSCFDMADemodulate` functions now support the narrowband Internet of Things (NB-IoT). You can perform perfect channel estimation and SC-FDMA demodulation with a subcarrier spacing of 3.75 kHz or 15 kHz.

NB-IoT Downlink Support: Generate downlink synchronization and reference signals

You can generate narrowband reference signals with the `lteNRS` function. You can also generate primary and secondary synchronization signals and their corresponding indices with these functions: `lteNPSS`, `lteNPSSIndices`, `lteNSSS`, and `lteNSSSIndices`.

Updated NB-IoT Examples: Perform NB-IoT NPUSCH and NPDSCH block error rate simulations

The NB-IoT NPUSCH Block Error Rate Simulation and NB-IoT NPDSCH Block Error Rate Simulation examples now model:

- A fading channel
- Perfect synchronization, perfect channel estimation, and equalization
- Codeword repetitions and performance comparisons with different repetitions

Uplink Carrier Aggregation Example: Generate an aggregated uplink waveform

The Uplink Carrier Aggregation Waveform Generation, Demodulation, and Analysis example shows how to:

1. Generate an LTE uplink waveform with carrier aggregation (CA).
2. Generate a modulated waveform for each component carrier (CC) configuration by calculating CA parameters.
3. Extract CCs by demodulating and filtering a waveform.
4. Measure the error vector magnitude and in-band emissions for any CC.

R2018b

Version: 3.0

New Features

Bug Fixes

256-QAM Uplink Support: Generate and decode uplink waveforms with Release 14 256-QAM modulation

The following set of PUSCH/UL-SCH and uplink control HARQ-ACK and RI functions now support 256-QAM modulation: `lteACKDecode`, `lteACKEncode`, `lteCQIEncode`, `ltePUSCH`, `ltePUSCHDecode`, `ltePUSCHIndices`, `lteRIDecode`, `lteRIEncode`, `lteRMCUL`, `lteRMCULTool`, `lteULDescramble`, `lteULSCH`, `lteULSCHDecode`, `lteULSCHDeinterleave`, `lteULSCHInfo`, and `lteULSCHInterleave`.

The `lteRMCUL` and `lteRMCULTool` waveform generation functions now support the 256-QAM specific ‘A17’ set of fixed-reference channel (FRC) settings: `'A17-1','A17-2','A17-3','A17-4','A17-5','A17-6'`.

NB-IoT Example: Model the narrowband Internet of Things (NB-IoT) transport and physical uplink shared channel

The NB-IoT Uplink Waveform Generation example shows how to generate LTE-Advanced Pro Release 13 Narrowband IoT (NB-IoT) uplink waveforms. The waveforms consist of the Narrowband Physical Uplink Shared Channel (NPUSCH) and the associated demodulation reference signals for test and measurement applications using LTE Toolbox.

LTE-M Downlink Example: Model the Release 13 (Cat-M1) and Release 14 (Cat-M2) LTE-M downlink physical channels and signals

The LTE-M Downlink Waveform Generation example shows how to create a downlink LTE-M transmission consisting of MTC Physical Downlink Control Channel (MPDCCH), the associated Physical Downlink Shared Channel (PDSCH) and the Physical Broadcast Channel (PBCH), including repetitions and frequency hopping.

LTE-M Uplink Example: Model the Release 13 (Cat-M1) and Release 14 (Cat-M2) LTE-M uplink shared channel and associated DM-RS

The LTE-M Uplink Waveform Generation example shows how to create an uplink LTE-M transmission consisting of the Physical Uplink Shared Channel (PUSCH) and the associated demodulation reference signals (DM-RS) including repetitions and frequency hopping.

MU-MIMO Link Example: Simulate a MU-MIMO end-to-end link

The PDSCH Throughput for Non-Codebook Based MU-MIMO Transmission Mode 9 (TM9) example shows how to measure the physical downlink shared channel (PDSCH) throughput performance in a multi-user multiple-input multiple-output (MU-MIMO) scenario with LTE Toolbox. The example uses non-codebook based transmission mode, TM9, with block diagonalization precoding.

NB-IoT Examples: NB-IoT NPUSCH block error rate simulation

The NB-IoT NPUSCH Block Error Rate Simulation example shows how LTE Toolbox can be used to create an NB-IoT PUSCH block error rate simulation under additive white Gaussian noise.

NB-IoT Support: NB-IoT SC-FDMA modulation and precoding/ deprecoding support added to existing functions

This release supports NB-IoT for the following existing functions:

- `lteSCFDMAModulate`
- `lteSCFDMAInfo`
- `lteULPrecode`
- `lteULDeprecode`

Functionality Being Removed or Changed

The 5G Library for LTE System Toolbox® has been removed for R2018b. The functions and reference examples comprising this library are available in 5G Toolbox , introduced in R2018b.

R2018a

Version: 2.6

New Features

Bug Fixes

NB-IoT Support: Model the narrowband Internet of Things (NB-IoT) transport and physical downlink shared channel

LTE System Toolbox now supports the narrowband transport and the physical downlink shared channel (NPDSCH) for the NB-IoT technique, according to Release 13 of the 3GPP LTE standard: `lteNRSIndices`, `lteNPDSCHIndices`, `lteNDLSCH`, `lteNDLSCHDecode`, `lteNPDSCH`, `lteNPDSCHDecode`

3GPP TR 36.873 3-D Channel Model: Model 3-D propagation conditions

The toolbox now provides the 3-D channel model described in 3GPP TR 36.873. To model 3-D fading environmental conditions, use the `lte3DChannel` System object.

User Equipment (UE) Detection Example: Detect UE IDs by analyzing an LTE downlink signal

This example enables you to detect user equipment (UE) identities by analyzing either an LTE downlink signal generated with LTE System Toolbox or a real waveform recovered from the air.

Simulink Example: Model a physical downlink shared channel (PDSCH) throughput conformance test using Simulink

Use the physical downlink shared channel (PDSCH) throughput simulation example to explore LTE System Toolbox capabilities in Simulink.

5G Library: Simulate 3GPP 5G radio technologies with new channel coding schemes (LDPC and Polar coding) and radio waveforms with variable subcarrier spacing

The 5G Library for LTE System Toolbox enables you to explore the behavior and performance of 3GPP 5G radio access technologies. To download it:

1. On the MATLAB **Home** tab, in the **Environment** section, click **Add-Ons** > **Get Add-Ons**.
2. In the Add-On Explorer window, browse or search for 5G.
3. Select the add-on and then click **Install**.

R2017b

Version: 2.5

New Features

Bug Fixes

V2X Sidelink Support: Model vehicle-to-vehicle wireless communications using LTE Release 14 functionality

LTE System Toolbox sidelink functionality has been extended to include V2X sidelink support of LTE Release 14.

The new V2X sidelink example explains how to perform block error rate simulation of the new sidelink functionality.

NB-IoT Example: Simulate a narrowband Internet of Things (NB-IoT) communications link over an AWGN channel model

This example shows how to create the NB-IoT narrowband physical downlink shared channel (NPDSCH) block error rate simulation. You can test its performance over an AWGN channel model, and the NB-IoT downlink time-domain waveform containing the NPDSCH and narrowband reference signal is generated.

5G Library: Simulate 3GPP 5G radio technologies with new waveforms and channel models

The 5G Library for LTE System Toolbox enables you to explore the behavior and performance of 3GPP 5G radio access technologies. To download it:

1. On the MATLAB **Home** tab, in the **Environment** section, click **Add-Ons** > **Get Add-Ons**.
2. In the Add-On Explorer window, browse or search for 5G.
3. Select the add-on and then click **Install**.

Additional Functions Implemented in MATLAB Code: Explore the MATLAB code of lteULSCH and ltePDSCH

The `lteULSCH` and `ltePDSCH` functions have been implemented using MATLAB code. You can now access the underlying code of these functions to customize the algorithms and functionality.

R2017a

Sidelink Receive Functionality: Perform sidelink link-level simulations that include timing synchronization, channel estimation, and equalization for ProSe direct communications

The following sidelink channel estimation and timing synchronization functions have been added to LTE System Toolbox: `lteSLFrameOffsetPSBCH`, `lteSLFrameOffsetPSCCH`, `lteSLFrameOffsetPSSCH`, `lteSLChannelEstimatePSBCH`, `lteSLChannelEstimatePSCCH`, and `lteSLChannelEstimatePSSCH`. For more information, see Sidelink Channels.

Sidelink PSCCH and PSSCH Throughput demonstrates using the PSCCH and PSSCH frame offset and channel estimation functions in a BLER simulation of sidelink control and shared channels.

TDD Configurations Support: Generate waveforms for all TDD configurations, including HARQ process mapping tables

The uplink and downlink generators can now create waveforms for any TDD configuration. The HARQ process mapping table creation was updated to support all TDD configurations. For more information, see `lteRMCDLTool` and `lteRMCULTool`.

For TDD, `lteRMCDL` now allows parameterization using the TDD configuration when the reference configuration is not provided, specifically when the `RC` parameter is absent or is empty, `[]`. When a supported reference configuration is specified, the TDD configuration defaults to 1 as specified by the RMC definitions in TS 36.101, Annex A. If scheduling is not specified via input parameters, all downlink and special subframes are assumed to be scheduled.

5G Library: Simulate 3GPP 5G radio technologies

The 5G library provides MATLAB functions for simulating 3GPP 5G new radio technologies. To download these functions:

1. On the MATLAB **Home** tab, in the **Environment** section, click **Add-Ons > Get Add-Ons**.
2. In the Add-On Explorer window, browse or search for 5G.
3. Select the add-on and then click **Install**.

Additional Functions Implemented in MATLAB Code: Explore the MATLAB code of ltePRACH, ltePRACHInfo, lteSymbolModulate, lteDLSCH, and lteDLSCHDecode

These functions have been implemented using MATLAB code — `ltePRACH`, `ltePRACHInfo`, `lteSymbolModulate`, `lteDLSCH`, and `lteDLSCHDecode`.

You can now access the underlying code of these functions to customize the algorithms and functions.

Transmission Modes 7 to 10 Throughput Example: Evaluate the performance of non-codebook-based transmission modes 7 to 10 in FDD and TDD scenarios

The example models throughput simulation performance for the physical downlink shared channel (PDSCH) in an FDD scenario. The 3GPP transmission modes explored include:

- TM7 — Non-codebook-based precoding for a single layer (Port 5)
- TM8 — Non-codebook-based precoding for up to two layers (Port 7–8), or single antenna port 7 or 8
- TM9 and TM10 — Non-codebook-based precoding for up to eight layers (Port 7–14), or single antenna port 7 or 8

Change to CBSBuffers representation used by lteDLSCHDecode

This change makes the CBSBuffers format consistent across LTE System Toolbox functions. The R2017a release changes the representation of the `CBSBuffers` field of the `statein` input and `stateout` output structure arrays. This change makes `lteDLSCHDecode` consistent with the format used by the other LTE System Toolbox low-level coding chain functions, such as `lteRateRecoverTurbo` and `lteULSCHDecode`.

Compatibility Considerations

Up to R2016b, the `CBSBuffers` field for `lteDLSCHDecode` contains the LLR soft buffer states ordered with the systematic (S) and parity (P) bits interleaved, such as *[S P1 P2 S P1 P2…]*, where P1 is a parity bit from the first encoder, and P2 is a parity bit from the second encoder.

In R2017a, these LLR soft buffer states are ordered in separate consecutive blocks, such as *[block of S, block of P1, block of P2]*.

R2016b

Version: 2.3

New Features

Bug Fixes

Sidelink Functionality: Model sidelink transmission and reception for ProSe direct communications

In this release, LTE System Toolbox adds proximity services (ProSe) transmission and reception components to support sidelink communication. Release 12 of the 3GPP LTE standard introduced this new device-to-device (D2D) interface, primarily allowing LTE to support public safety communication systems.

LTE System Toolbox sidelink transmission and reception functions have been added for broadcast, control, and shared channels. ProSe direct communication enables direct UE to multiple UE communication (group communication) without data transmission on the uplink or downlink. ProSe direct communication is allowed for public safety applications only and supports one or more UEs being out of network or out of frequency coverage.

For a list of sidelink functions and further details, see Sidelink Channels.

EPDCCH Receiver: Perform end-to-end EPDCCH BLER simulation

This release adds enhanced physical downlink control channel (EPDCCH) receiver support including search space creation, physical channel demodulation, and blind search. For further details, see Enhanced Physical Downlink Control Channel (EPDCCH) Conformance Test.

Transmission Modes 7 to 10 Throughput Example: Evaluate the performance of non-codebook-based transmission modes 7 to 10

The PDSCH TDD Throughput for Non-Codebook Based Precoding Schemes: Port 5 (TM7), Port 7 or 8 or Port 7-8 (TM8), Port 7-14 (TM9 and TM10) example models throughput simulation performance for the physical downlink shared channel (PDSCH) in a TDD scenario. The 3GPP transmission modes explored include:

- TM7 — Non-codebook-based precoding for a single layer (Port 5)
- TM8 — Non-codebook-based precoding for up to two layers (dual layer Port 7-8, or single antenna port 7 or 8)
- TM9 and TM10 — Non-codebook based precoding for up to eight layers (up to eight layers Port 7-14 or single antenna port 7 or 8)

Waveform Generation Enhancements: Generate sustained data rate waveforms and directly control the code rate

This release adds several enhancements for waveform generation and analysis:

- Previously, the only subframe 5 data that could be generated was OCNG. Now you can transmit reference PDSCH data in subframe 5. For details, see `lteRMCDLTool` and `lteRMCDL`.
- Support for generating sustained data rate RMC waveforms. For details, see `lteRMCDLTool` and `lteRMCDL`.
- Direct control over target code rate. For details, see `lteRMCDL` and `lteRMCUL`.
- Simulation support added to `lteDLConformanceTestTool` for Transmission modes 7–10. Transmission modes 7–10 include demodulation reference signals (DM-RS) for channel estimation when demodulating PDSCH.

- The LTE Parameterization for Waveform Generation and Simulation example shows the steps involved and the different ways to parameterize end-to-end simulations and static waveform generation using LTE System Toolbox.

Functions now implemented in MATLAB Code

The `lteOFDMModulate` and `lteSCFDMAModulate` functions are now implemented in MATLAB code. You can access the underlying code to customize the algorithms and functions.

R2016a

Version: 2.2

New Features

Bug Fixes

Release 12 Alternative Codebook: Model CSI reporting with Release 12 alternative codebook, optimized for Multiuser-MIMO applications

These functions now support Release 12 alternative codebook (four-antenna downlink), as specified in TS 36.213, Table 7.2.4-0A to Table 7.2.4-0D:

- `lteCSICodebook`
- `ltePMIInfo`
- `ltePMISelect`
- `lteRISelect`
- `lteCQISelect`

Release 10 and 11 DCI Message Enhancements: Create, decode, and search for all DCI messages for LTE Releases 10 and 11

These functions now fully support 3GPP Release 10 and 11 DCI message creation, manipulation, and decoding:

- `lteDCI`
- `lteDCIDecode`
- `lteDCIInfo`
- `ltePDCCHSearch`

Fixed Reference Channel A.11-1 Waveform Generation: Create waveforms with TTI bundling and Release 12 enhanced HARQ patterns for VoIP applications

The `lteRMCUL` and `lteRMCULTool` functions now support 3GPP Release 12 uplink fixed reference channel A11-1. The FRC A11-1 specifies waveform generation of PUSCH with TTI bundling and the enhanced HARQ pattern.

EPDCCH Channel Estimation: Estimate the channel for EPDCCH equalization and reception

The `lteDLChannelEstimate` function now supports EPDCCH DM-RS channel estimation, which can be used for equalization and reception of EPDCCH.

R2015b

Release 12 256-QAM: Simulate small cell PDSCH 256-QAM modulation and coding schemes

`lteTBS`, `lteMCS`, and all PDSCH/DL-SCH related functions have been updated adding support for 256-QAM modulation. These functions extend TBS tables and add the alternative PDSCH MCS table for Release 12 MCS determination.

Release 11 Multiple Zero Power CSI-RS Bitmaps: Model multicell ZP CSI-RS patterns

`lteCSIRS`, `lteCSIRSIndices`, `lteEPDCCHIndices`, and `ltePDSCHIndices` functions now support multiple zero-power CSI-RS resources. Using these functions when assigning resource elements, a transmitting cell can now avoid assigning resource elements used by other cells for CSI-RS transmission.

Release 11 PUSCH/PUCCH DRS Virtual Identities: Model uplink Release 11 Coordinated Multipoint (CoMP) scenarios

The following functions now support virtual cell identities and alternative scrambling, enabling modeling of uplink Release 11 Coordinated Multipoint (CoMP) scenarios with the LTE System Toolbox:

`ltePUSCHDRS`	`lteULChannelEstimate`	`lteULChannelEstimatePUCCH2`
`ltePUCCH1DRS`	`lteULFrameOffset`	`lteULFrameOffsetPUCCH2`
`ltePUCCH2DRS`	`lteULChannelEstimatePUCCH1`	`lteULChannelEstimatePUCCH3`
`ltePUCCH3DRS`	`lteULFrameOffsetPUCCH1`	`lteULFrameOffsetPUCCH3`
`lteRMCULTool`	`ltePUCCH2DRSDecode`	

Cell Search Enhancements: Detect multiple cells in an LTE downlink waveform

The `lteCellSearch` now enables you to:

- Detect multiple cells
- Perform post-FFT-based SSS detection
- Compare the strength of detected cells

The following feature examples show the cell search enhancements:

- Reference Signal Measurements (RSRP,RSSI,RSRQ) for Cell Reselection determines the quality of the detected cells. The cell reselection test environment, described in TS 36.133 Annex A.4.2.2.1, is configured in this example.
- Cell Search, MIB and SIB1 Recovery fully synchronizes, demodulates and decodes live eNodeB signal.

- Time Difference Of Arrival Positioning Using PRS calculates the position of a User Equipment (UE) within a network of eNodeBs via the Time Difference Of Arrival (TDOA) positioning approach in conjunction with the Release 9 Positioning Reference Signal (PRS).

Waveform Generation: Improved control of PDCCH, DCI, and OCNG for test and measurement

The uplink and downlink waveform generator functions (`lteRMCDLTool`, `lteRMCDL`, `lteRMCULTool`, and `lteRMCUL`) now enable:

- Uplink waveform generator control of the bandwidth associated with each RMC
- Downlink waveform generator control of the DCI format, the PDCCH format, and PDCCH power. OCNG generation for PDSCH and PDCCH, has been enhanced as follows:
  - New parameters to enable or disable the PDSCH and PDCCH OCNG
  - OCNG power control
  - Control over the RNTI of the PDSCH OCNG, modulation scheme, and the transmission scheme

The PDCCH Conformance Test feature example demonstrates some of the enhanced waveform generation controls.

LTE Obsolete Interface Support

This interface is provided for backwards compatibility. It will now result in runtime errors indicating which new functions to use.

Compatibility Considerations

Previous versions of the LTE System Toolbox product contained a different set of function names. The term Obsolete LTE Toolbox interface refers to these previous versions, prior to version 1.0. If you wrote scripts using any of the old function names used in previous versions, you should modify the scripts to use the new function names. Also, you should modify many of the scripts to expect column vectors for output arguments where row vectors were previously returned.

R2015a

Version: 2.0

New Features

Bug Fixes

UMTS Downlink and Uplink Waveform Generation Functions: Generate standard-compliant W-CDMA, HSPA and HSPA+ signals

This release adds UMTS (W-CDMA, HSPA and HSPA+) waveform generation functions, `umtsDownlinkWaveformGenerator` and `umtsUplinkWaveformGenerator`. Additionally reference channel functions, `umtsDownlinkReferenceChannels` and `umtsUplinkReferenceChannels`, are provided so that you can readily produce a configuration structure initialized to define RMC, FRC H-Set and test models defined in 3GPP standards. The reference channel function output configuration structure serves as input to the associated waveform generation function.

Coordinated Multipoint (CoMP) Transmission and Reception Simulation: Mitigate interference and improve performance at the edge of an LTE cell

This release features an example demonstrating CoMP dynamic interference mitigation cooperation between multiple base stations.

- CoMP Dynamic Point Selection with Multiple CSI Processes

SIB1 Message PDSCH Support: Generate and receive LTE downlink waveforms carrying SIB1 for cell search and network access

This release enables you to generate LTE waveforms carrying SIB1 message using the `lteRMCDLTool` function.

TM9/TM10 RMC waveform generation: Create TM9/TM10 waveforms containing CSI-RS for channel quality measurements

The `lteRMCDL` function now returns the 3GPP standard defined CSI-RS RMC configurations and the `lteRMCDLTool` can now generate these waveforms containing CSI-RS. New RMCs added to `lteRMCDL` and the `lteRMCDLTool` GUI in this release are `'R.43'`, `'R.44'`, `'R.45'`, `'R.45-1'`, `'R.48'`, `'R.50'`, and `'R.51'`.

Additional Featured Examples: SIB1, EPDCCH, working with live LTE signals, multicell interference, EVM measurement, HDL verification, UMTS

This release adds and/or enhances several examples

- Cell Search, MIB and SIB1 Recovery
- Enhanced Physical Downlink Control Channel (EPDCCH) Generation
- Working with Live LTE Signals using Software-Defined Radio (SDR)
- Effect of Inter-Cell Interference on PDSCH Throughput
- PDSCH Error Vector Magnitude (EVM) Measurement
- Verification of HDL Implementation of LTE OFDM Modulator and Detector
- UMTS Downlink Waveform Generation

- UMTS Uplink Waveform Generation

R2014b

Version: 1.2

New Features

Bug Fixes

Enhanced physical downlink control channel (EPDCCH) and its demodulation reference signal (DM-RS) generation functions in support of 3GPP Release 11

R2014b adds support for the creation of Release 11 compliant enhanced physical downlink control channel (EPDCCH) transmissions. For details, see the command line help for `lteEPDCCH` and `lteEPDCCHIndices`. Additionally, `lteEPDCCHDMRS` and `lteEPDCCHDMRSIndices` allow you to generate the associated demodulation reference signals (DM-RS).

Channel quality indicator (CQI) and rank indicator (RI) estimation functions for modulation and coding scheme (MCS) selection

R2014b adds support for adaptive modulation and coding scheme (MCS) selection. `lteCQISelect` performs channel quality indicator (CQI) estimation, `lteRISelect` performs rank indicator (RI) estimation, and `lteMCS` provides a lookup between MCS values and the corresponding transport block size (TBS) and modulation order.

Unifying function for extracting physical channel symbols and signals from a resource grid

R2014b adds support for extracting physical channel symbols and signals from a resource grid. For details, see the command-line help for `lteExtractResources`.

Zero-power channel state information reference signals (CSI-RS) generation functions in support of 3GPP Release 10

R2014b adds support for zero-power CSI-RS. New parameters added to `lteCSIRS`, `lteCSIRSIndices`, and `ltePDSCHIndices` allow you to define zero-power CSI-RS via the standardized 16-bit bitmap representation.

R2014a

Version: 1.1

New Features

Compatibility Considerations

Standard-compliant models for LTE and LTE-Advanced (Releases 8, 9, and 10)

The LTE System Toolbox product provides standard-compliant functions and tools for the design, simulation, and verification of long-term evolution (LTE) and LTE-Advanced communications systems. LTE-Advanced comprises changes made to releases 9 and 10 of the LTE Standard.

End-to-end physical layer transmit and receive processing functions, including OFDM (downlink) and SC-FDMA (uplink)

The LTE System Toolbox product provides standard-compliant functions for end-to-end physical layer transmit and receive processing. These functions include OFDM modulation for downlink and SC-FDMA modulation for uplink.

MIMO antenna transmission and UE-specific beamforming functions

The LTE System Toolbox product provides standard-compliant functions for multiple-input, multiple-output (MIMO) antenna transmission and user equipment (UE)-specific beamforming.

Channel estimation, synchronization, and MIMO receiver functions

The LTE System Toolbox product provides standard-compliant MIMO receiver functions for synchronization, channel estimation, equalization, and signal recovery procedures.

Standard-compliant propagation channel models

The LTE System Toolbox product provides standard-compliant functions for modeling propagation channels. These functions include models for MIMO fading channel, EPA, EVA, and ETU, moving propagation channel, and high-speed train MIMO channel.

Test models and reference measurement channel (RMC) waveform generators

The LTE System Toolbox product provides standard-compliant functions and tools for generating E-UTRA test models (E-TM) and reference measurement channel (RMC) waveforms.

Interactive tools for conformance and BER testing

The LTE System Toolbox product provides interactive tools for conformance and BER testing. You can create and reuse a conformance test bench to verify that your designs, prototypes, and implementations comply with the LTE standard.

Recovery of low-level parameters, such as cell identity

The LTE System Toolbox product provides for the recovery of low-level parameters, such as cell identity.

Apps for generating waveforms and analyzing throughput

This release adds the following four new apps to the MATLAB apps gallery.

- **LTE Downlink RMC Generator** — used for selection of parameters for and generation of downlink reference measurement channel (RMC) waveforms. For more information, see `lteRMCDLTool`
- **LTE Uplink RMC Generator** — used for selection of parameters for and generation of uplink reference measurement channel (RMC) waveforms. For more information, see `lteRMCULTool`
- **LTE Test Model Generator** — used for selection of parameters for and generation of E-UTRA test model (E-TM) waveforms. For more information, see `lteTestModelTool`
- **LTE Throughput Analyzer** — used to perform the PDSCH demodulation performance test and plot throughput performance graphs. For more information, see `lteDLConformanceTestTool`

Function names and output behavior changed

Previous versions of the LTE System Toolbox product used different function names. In version 1.0, the LTE System Toolbox product contains an entirely new set of function names. Also, many functions in previous versions of the LTE System Toolbox product returned row vectors for output arguments. In version 1.0, many of the new equivalent functions return column vectors for output arguments.

Compatibility Considerations

If you wrote scripts using any of the old function names used in previous versions, you must modify the scripts to use the new function names in the LTE System Toolbox product, version 1.0. Also, you must modify many of the scripts to expect column vectors for output arguments where row vectors were previously returned. Refer to the following table for a mapping of the previous function names to their new equivalent function names.

In R2014a, by default, all the functions listed in the **Previous Function Name** column are on the MATLAB path. To remove these functions from the path, call the `rmlteobsolete` function. To add these functions to the path again, call the `addlteobsolete` function.

Previous Function Name	New Function Name
`LteACKDecode`	`lteACKDecode`
`LteACKEncode`	`lteACKEncode`
`LteBCH`	`lteBCH`
`LteBCHDecode`	`lteBCHDecode`
`LteCFI`	`lteCFI`
`LteCFIDecode`	`lteCFIDecode`
`LteCQIDecode`	`lteCQIDecode`
`LteCQIEncode`	`lteCQIEncode`
`LteCRC`	`lteCRCEncode`
`LteCRCDecode`	`lteCRCDecode`
`LteCSICodebook`	`lteCSICodebook`

Previous Function Name	New Function Name
LteCSIRS	lteCSIRS
LteCSIRSIndices	lteCSIRSIndices
LteCellRS	lteCellRS
LteCellRSIndices	lteCellRSIndices
LteCellSearch	lteCellSearch
LteCodeBlkDeseg	lteCodeBlockDesegment
LteCodeBlkSeg	lteCodeBlockSegment
LteConvCode	lteConvolutionalEncode
LteConvDecode	lteConvolutionalDecode
LteDCI	lteDCI
LteDCIDecode	lteDCIDecode
LteDCIDims	lteDCIInfo
LteDCIEncode	lteDCIEncode
LteDLChannelEstimation	lteDLChannelEstimate
LteDLConformanceTestBench	lteDLConformanceTestTool
LteDLDeprecoder	lteDLDeprecode
LteDLFrameOffset	lteDLFrameOffset
LteDLPerfectChannelEstimation	lteDLPerfectChannelEstimate
LteDLPrecoder	lteDLPrecode
LteDLResourceGrid	lteDLResourceGrid
LteDLResourceGridDims	lteDLResourceGridSize
LteDLSCH	lteDLSCH
LteDLSCHDecode	lteDLSCHDecode
LteDLSCHDims	lteDLSCHInfo
LteDMRS	lteDMRS
LteDMRSIndices	lteDMRSIndices
LteDuplexDims	lteDuplexingInfo
LteEVM	lteEVM
LteEqualizeMIMO	lteEqualizeMIMO
LteEqualizeMMSE	lteEqualizeMMSE
LteEqualizeULMIMO	lteEqualizeULMIMO
LteEqualizeZF	lteEqualizeZF
LteFadingChan	lteFadingChannel
LteFreqCorrect	lteFrequencyCorrect
LteFreqOffset	lteFrequencyOffset
LteHSTChan	lteHSTChannel

Previous Function Name	New Function Name
LteLayerDemapper	lteLayerDemap
LteLayerMapper	lteLayerMap
LteMIB	lteMIB
LteMovingChan	lteMovingChannel
LteOFDM	lteOFDMModulate
LteOFDMDemod	lteOFDMDemodulate
LteOFDMDims	lteOFDMInfo
LtePBCH	ltePBCH
LtePBCHDecode	ltePBCHDecode
LtePBCHIndices	ltePBCHIndices
LtePBCHPRBS	ltePBCHPRBS
LtePCFICH	ltePCFICH
LtePCFICHDecode	ltePCFICHDecode
LtePCFICHDims	ltePCFICHInfo
LtePCFICHIndices	ltePCFICHIndices
LtePCFICHPRBS	ltePCFICHPRBS
LtePDCCH	ltePDCCH
LtePDCCHDecode	ltePDCCHDecode
LtePDCCHDeinterleave	ltePDCCHDeinterleave
LtePDCCHDims	ltePDCCHInfo
LtePDCCHIndices	ltePDCCHIndices
LtePDCCHInterleave	ltePDCCHInterleave
LtePDCCHPRBS	ltePDCCHPRBS
LtePDCCHSearch	ltePDCCHSearch
LtePDCCHSpace	ltePDCCHSpace
LtePDSCH	ltePDSCH
LtePDSCHDecode	ltePDSCHDecode
LtePDSCHIndices	ltePDSCHIndices
LtePDSCHPRBS	ltePDSCHPRBS
LtePHICH	ltePHICH
LtePHICHDecode	ltePHICHDecode
LtePHICHDeprecoder	ltePHICHDeprecode
LtePHICHDims	ltePHICHInfo
LtePHICHIndices	ltePHICHIndices
LtePHICHPRBS	ltePHICHPRBS
LtePHICHPrecoder	ltePHICHPrecode

Previous Function Name	New Function Name
LtePHICHTxDivDecode	ltePHICHTransmitDiversityDecode
LtePMIDims	ltePMIInfo
LtePMISelection	ltePMISelect
LtePRACH	ltePRACH
LtePRACHDetect	ltePRACHDetect
LtePRACHDims	ltePRACHInfo
LtePRBFromDCI	lteDCIResourceAllocation
LtePRBS	ltePRBS
LtePRS	ltePRS
LtePRSIndices	ltePRSIndices
LtePSS	ltePSS
LtePSSIndices	ltePSSIndices
LtePUCCH1	ltePUCCH1
LtePUCCH1DRS	ltePUCCH1DRS
LtePUCCH1DRSIndices	ltePUCCH1DRSIndices
LtePUCCH1Decode	ltePUCCH1Decode
LtePUCCH1Indices	ltePUCCH1Indices
LtePUCCH2	ltePUCCH2
LtePUCCH2DRS	ltePUCCH2DRS
LtePUCCH2DRSDecode	ltePUCCH2DRSDecode
LtePUCCH2DRSIndices	ltePUCCH2DRSIndices
LtePUCCH2Decode	ltePUCCH2Decode
LtePUCCH2Indices	ltePUCCH2Indices
LtePUCCH2PRBS	ltePUCCH2PRBS
LtePUCCH3	ltePUCCH3
LtePUCCH3DRS	ltePUCCH3DRS
LtePUCCH3DRSIndices	ltePUCCH3DRSIndices
LtePUCCH3Decode	ltePUCCH3Decode
LtePUCCH3Indices	ltePUCCH3Indices
LtePUCCH3PRBS	ltePUCCH3PRBS
LtePUSCH	ltePUSCH
LtePUSCHDRS	ltePUSCHDRS
LtePUSCHDRSIndices	ltePUSCHDRSIndices
LtePUSCHDecode	ltePUSCHDecode
LtePUSCHDeprecoder	ltePUSCHDeprecode
LtePUSCHIndices	ltePUSCHIndices

Previous Function Name	New Function Name
LtePUSCHPrecoder	ltePUSCHPrecode
LteRIDecode	lteRIDecode
LteRIEncode	lteRIEncode
LteRMCDL	lteRMCDL
LteRMCDLTool	lteRMCDLTool
LteRMCUL	lteRMCUL
LteRMCULTool	lteRMCULTool
LteRateMatchConv	lteRateMatchConvolutional
LteRateMatchTurbo	lteRateMatchTurbo
LteRateRecoverConv	lteRateRecoverConvolutional
LteRateRecoverTurbo	lteRateRecoverTurbo
LteResourceGrid	lteResourceGrid
LteResourceGridDims	lteResourceGridSize
LteSCFDMA	lteSCFDMAModulate
LteSCFDMADemod	lteSCFDMADemodulate
LteSCFDMADims	lteSCFDMAInfo
LteSRS	lteSRS
LteSRSDims	lteSRSInfo
LteSRSIndices	lteSRSIndices
LteSSS	lteSSS
LteSSSIndices	lteSSSIndices
LteSymbolDemod	lteSymbolDemodulate
LteSymbolMod	lteSymbolModulate
LteTBS	lteTBS
LteTestModel	lteTestModel
LteTestModelTool	lteTestModelTool
LteTurboCode	lteTurboEncode
LteTurboDecode	lteTurboDecode
LteTxDiversityDecode	lteTransmitDiversityDecode
LteUCI3Decode	lteUCI3Decode
LteUCI3Encode	lteUCI3Encode
LteUCIDecode	lteUCIDecode
LteUCIEncode	lteUCIEncode
LteUeRS	Removed. Use lteDMRS instead.
LteUeRSIndices	Removed. Use lteDMRSIndices instead.
LteULChannelEstimation	lteULChannelEstimate

Previous Function Name	New Function Name
`LteULChannelEstimationPUCCH1`	`lteULChannelEstimatePUCCH1`
`LteULChannelEstimationPUCCH2`	`lteULChannelEstimatePUCCH2`
`LteULChannelEstimationPUCCH3`	`lteULChannelEstimatePUCCH3`
`LteULDeprecoder`	`lteULDeprecode`
`LteULDescrambler`	`lteULDescramble`
`LteULFrameOffset`	`lteULFrameOffset`
`LteULFrameOffsetPUCCH1`	`lteULFrameOffsetPUCCH1`
`LteULFrameOffsetPUCCH2`	`lteULFrameOffsetPUCCH2`
`LteULFrameOffsetPUCCH3`	`lteULFrameOffsetPUCCH3`
`LteULPMIDims`	`lteULPMIInfo`
`LteULPMISelection`	`lteULPMISelect`
`LteULPerfectChannelEstimation`	`lteULPerfectChannelEstimate`
`LteULPrecoder`	`lteULPrecode`
`LteULResourceGrid`	`lteULResourceGrid`
`LteULResourceGridDims`	`lteULResourceGridSize`
`LteULSCH`	`lteULSCH`
`LteULSCHDecode`	`lteULSCHDecode`
`LteULSCHDeinterleave`	`lteULSCHDeinterleave`
`LteULSCHDims`	`lteULSCHInfo`
`LteULSCHInterleave`	`lteULSCHInterleave`
`LteULScrambler`	`lteULScramble`
`LteVersion`	Removed. Use the MATLAB `version` function instead.
`LteWarning`	`lteWarning`
`LteZadoffChu`	Removed. Use `lteZadoffChuSeq` in the Communications Toolbox™ product instead.